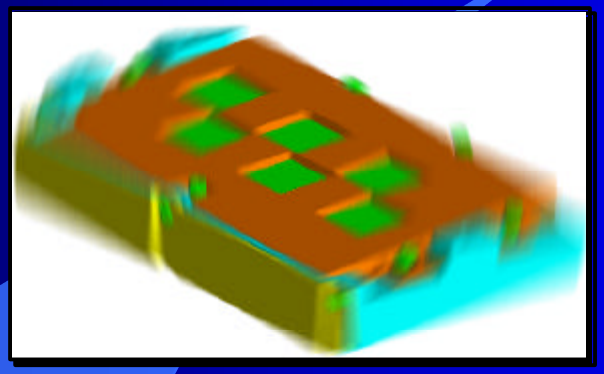
FEMCI Conference

A Multi-Disciplinary Approach to Calculate Displacement Due to Random Vibration For A Space Based Focal Plane



Anthony J. Davenport
Senior Mechanical Engineer
Northrop Grumman, ESSS

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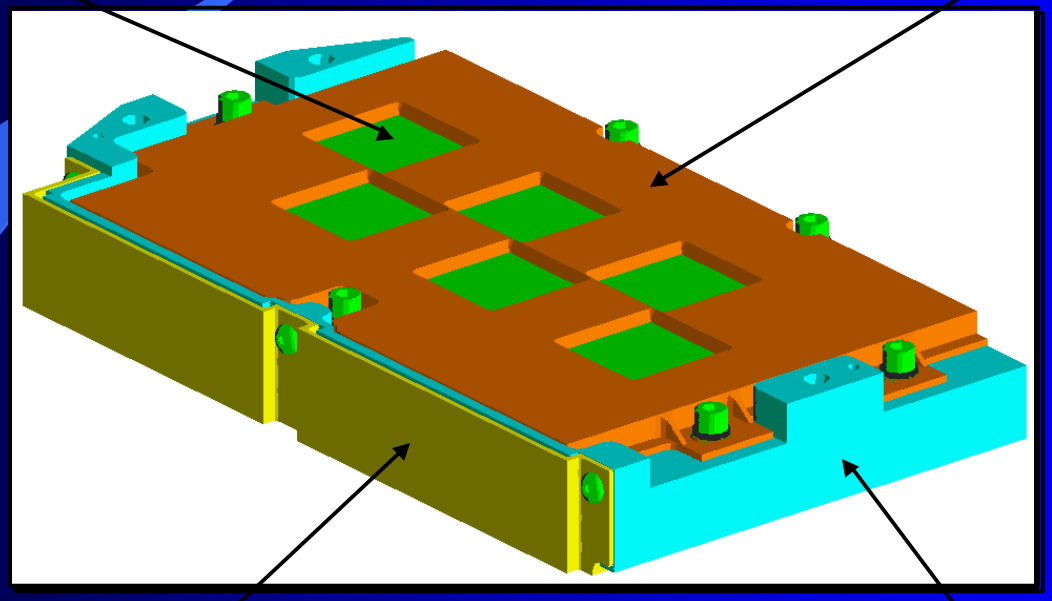
Focal Plane Geometry



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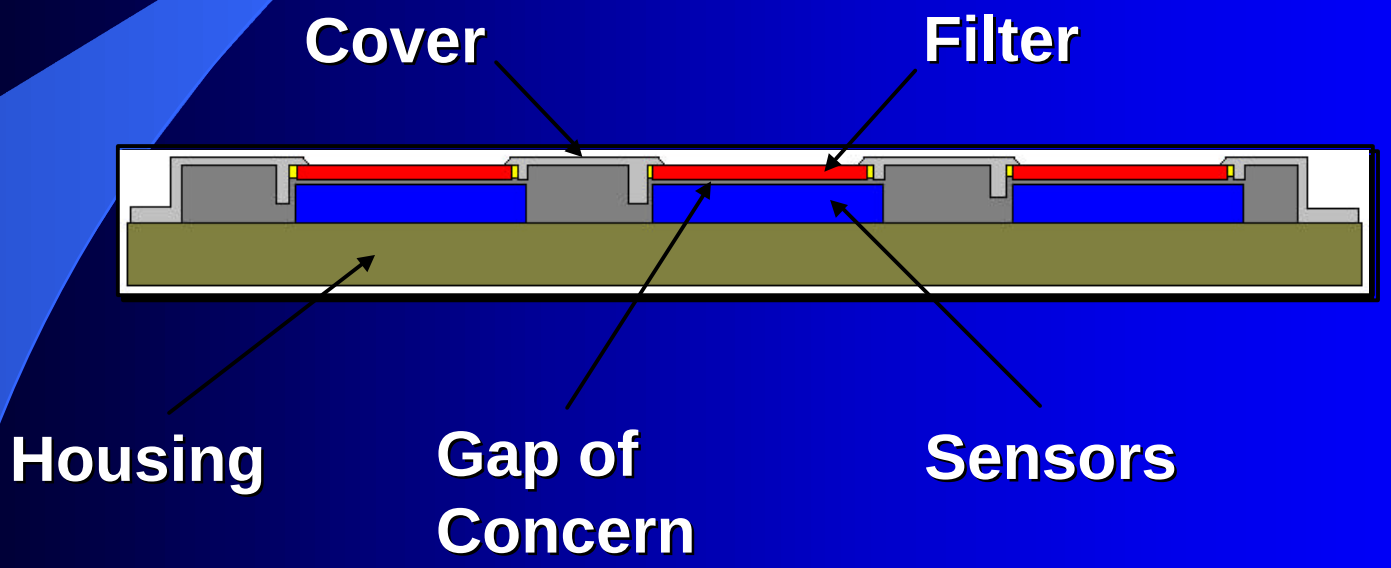
So What Is The Problem?

1. Out of Plane Bowing from Cryogenic Loading
2. Random Vibration Displacement of the Cover
3. Lack of Material Properties (Adhesives)



Focal Plane Cross-Section

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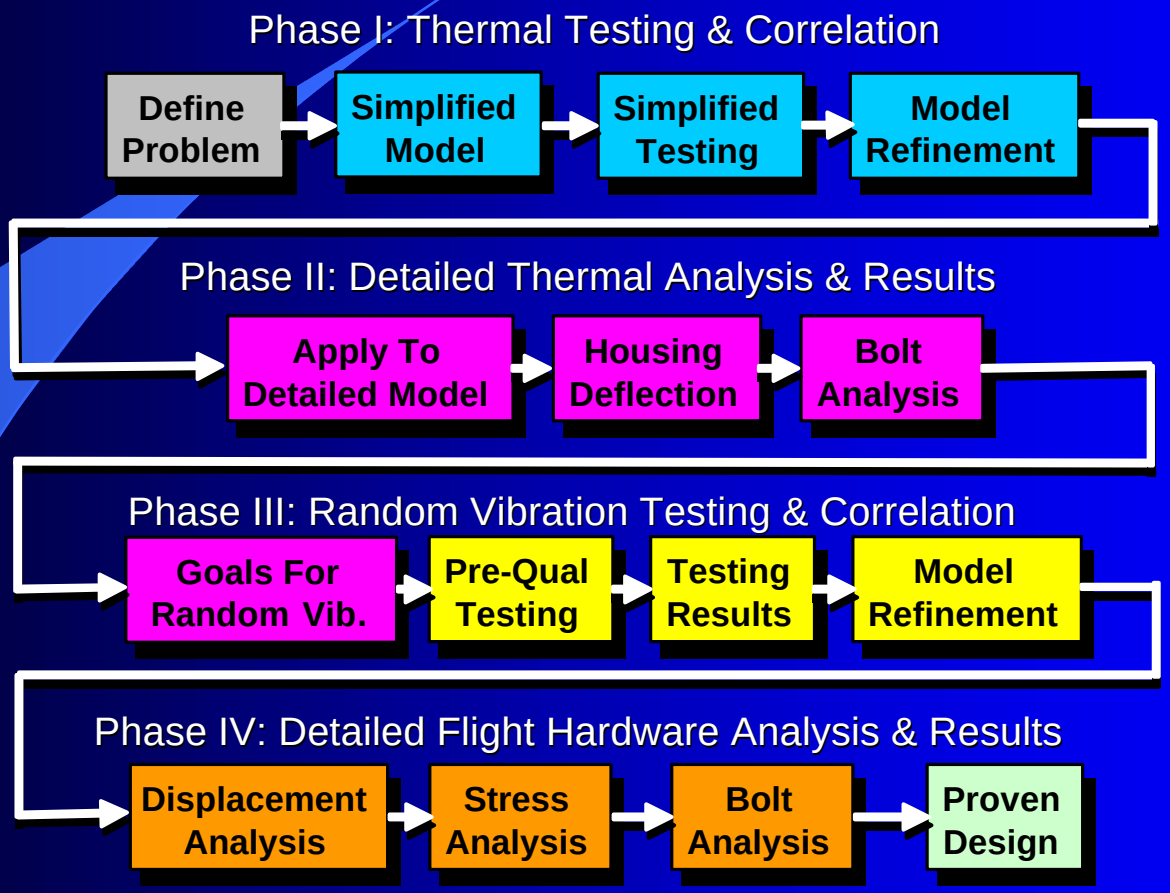
Design & Analysis Path for the Focal Plane



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Thermal Expansion Analysis Method

- Create a simplified model in PTC's Mechanica using mechanical properties determined by the NG materials group.
  - Run model between 295 ºK to 110 ºK (ΔT = 185 ºK)
  - Examine relative displacement in the out-of-plane direction (Z)
- Compare results to testing completed in laboratory and correlate model.
- Apply what is learned to detailed model.

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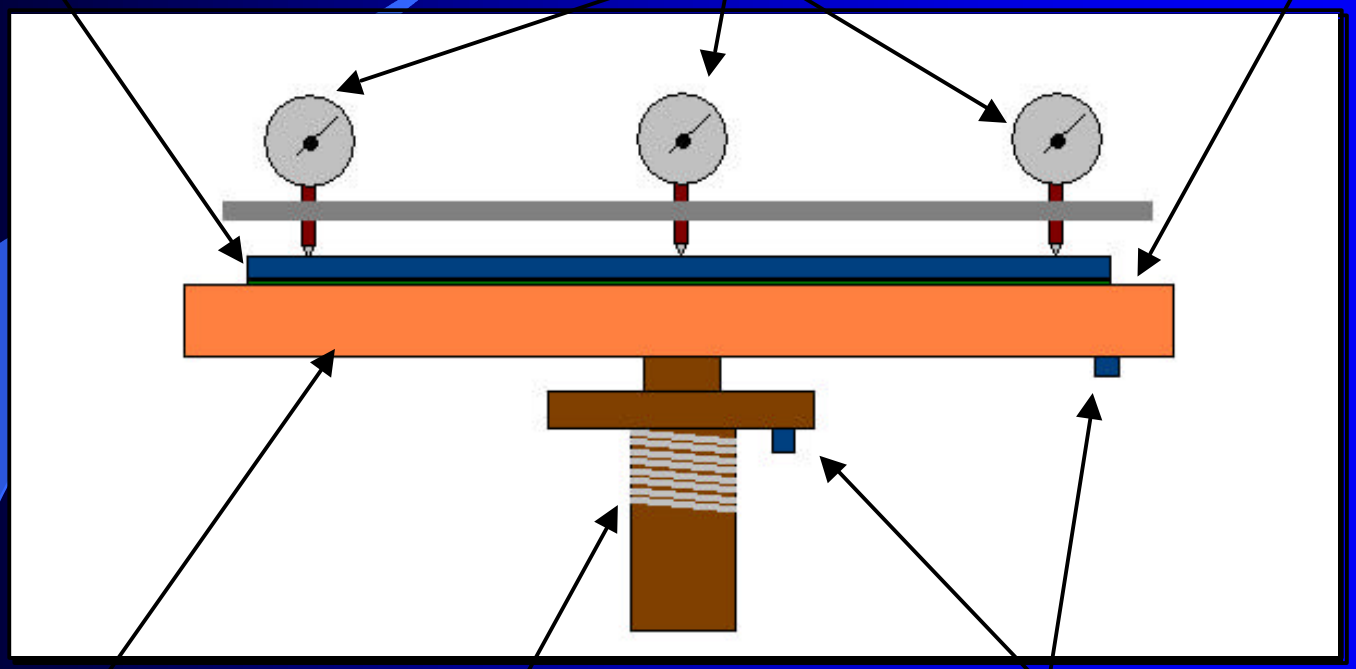
Simplified Test Model



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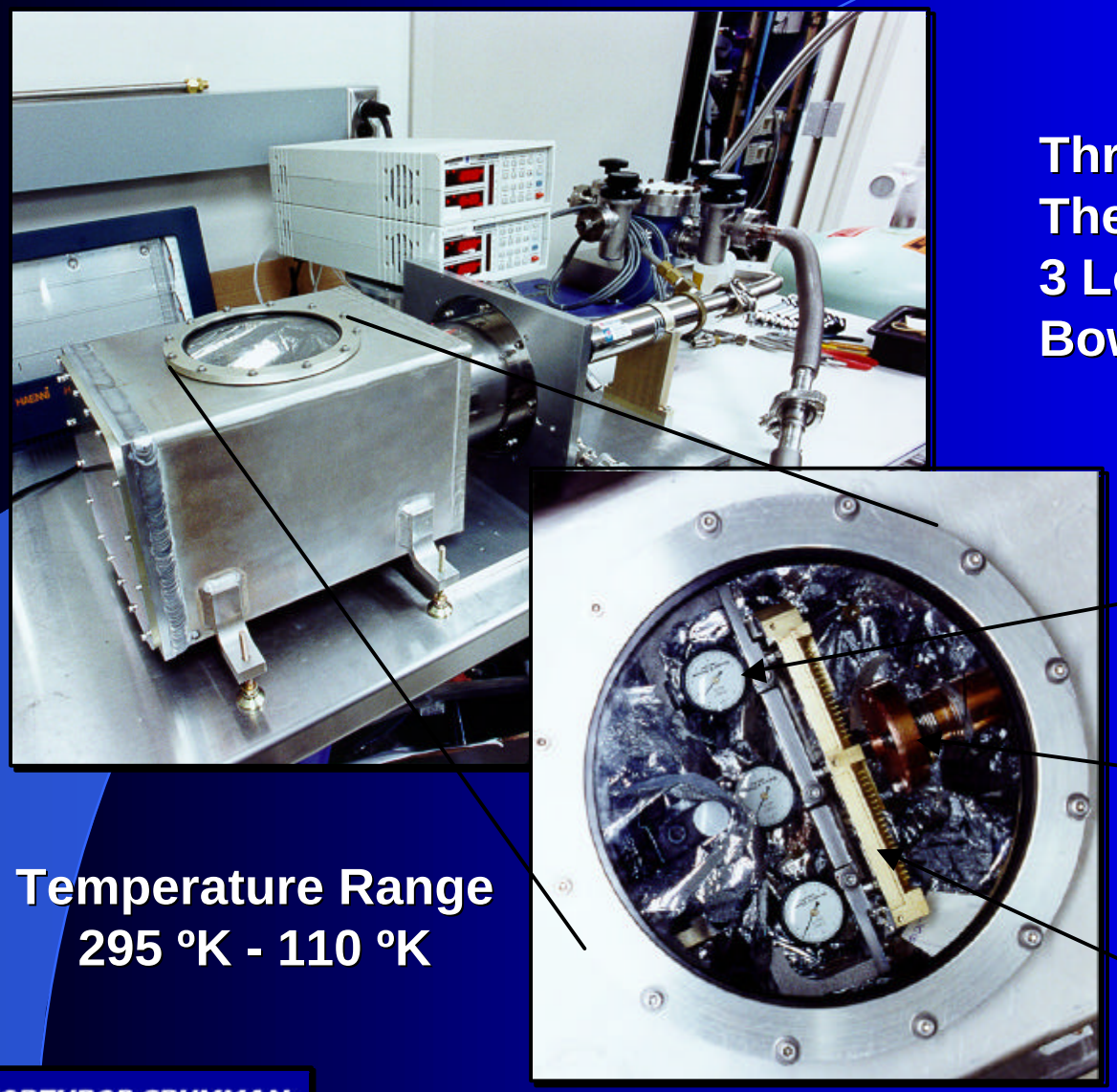
Laboratory Test Setup



Three Dial Gages Touch
The Focal Plane in
3 Locations to Measure
Bowing in Focal Plane

Measuring Dials (x3)

Cold Finger & Heater

Focal Plane

Temperature Range
295 ºK - 110 ºK

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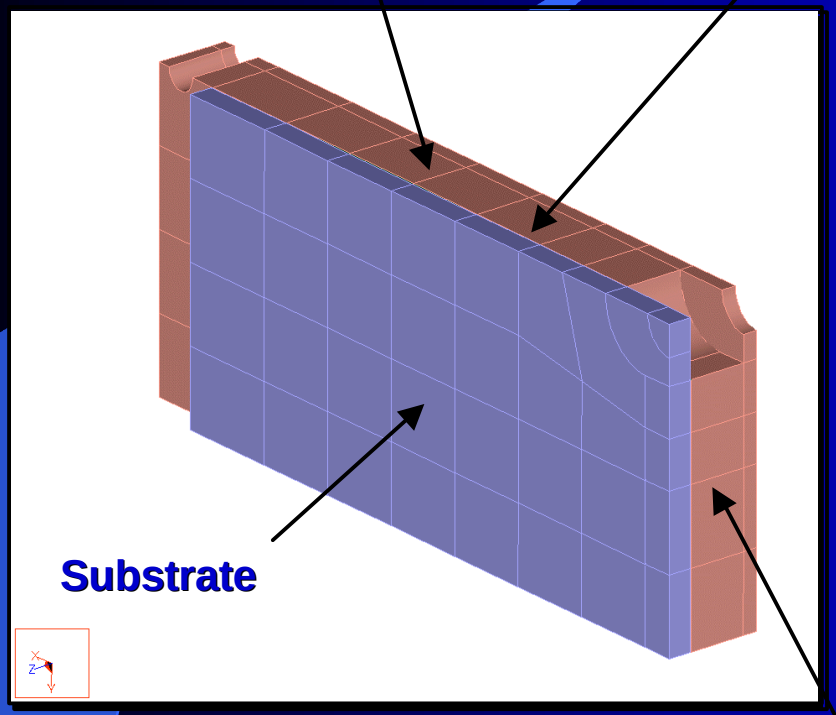
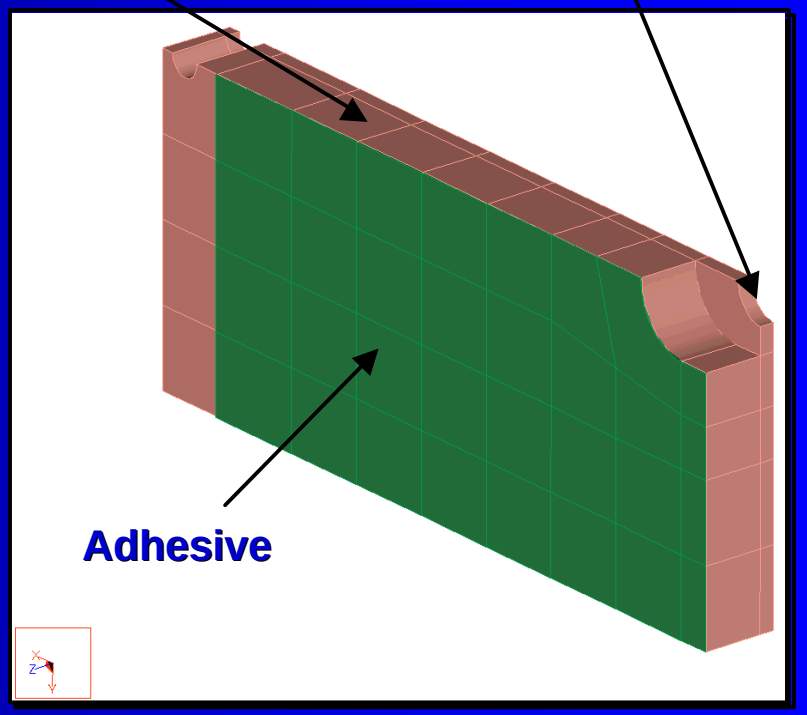
1/4 Simplified Analysis Model





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Relative Displacement Results From Testing & Analysis

Analysis Model

		Displacement		
Adhesive	Thickness [mil]	Trial #1 [mil	Trial #2 [mil]	Average [mil]
A	5 +/- 0.1	-1.688	-1.413	-1.551
B	8 +/- 0.1	-0.775	-0.878	-0.827

Testing

		Displacement		
Adhesive	Thickness [mil]	Minimum [mil]	Maximum [mil]	Relative [mil]
A	5 +/- 0.1	-1.979	-0.424	-1.555
B	8 +/- 0.1	-2.895	-2.046	-0.849

Comparison

		Displacement		
Adhesive	Thickness [mil]	Testing [mil]	Analysis [mil]	% Difference
A	5 +/- 0.1	-1.551	-1.555	-0.29%
B	8 +/- 0.1	-0.827	-0.849	-2.72%

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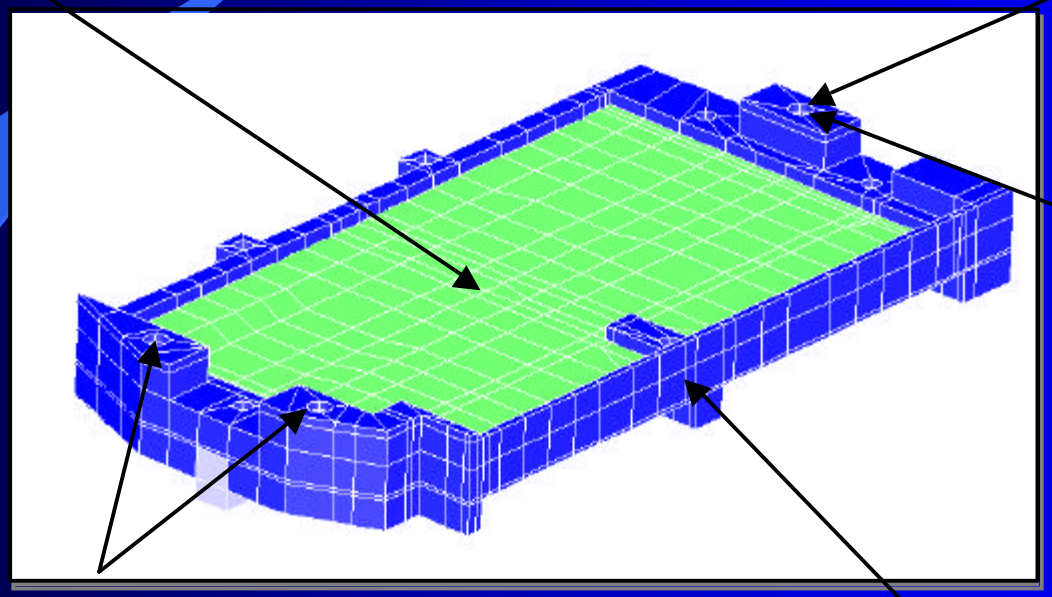
Detailed Analysis Model

Focal Plane Bows 5.3 μm, or +/- 2.6 μm Across a Mid-Plane



Uniform Temperature Load: Cure to Cryogenic (295 °K to 110 °K)

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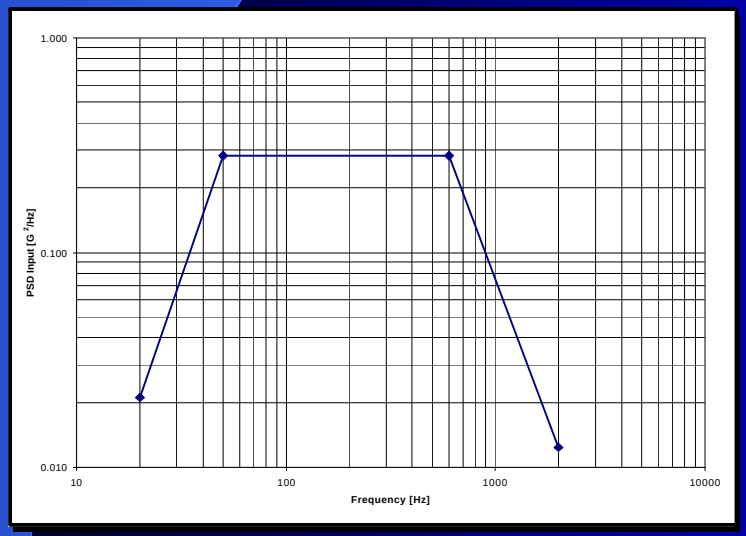
Random Vibration Derived Requirements

From Cryogenic Analysis →

Source	Value [in]
Allowable (To Reduce Stray Light)	0.005
R_{ss}'d Value of SCA Stack-Up	-0.00225
Cryogenic Bowing	-0.0002
Outer vs. Inner SCA Tolerance	-0.0005
Allowable for Random Vibration Deflection	**0.00205**



Frequency [Hz]	PSD Input [G^2/Hz]
20	0.021
50	0.282
600	0.282
2000	0.012
Overall (G_{rms})	**15.75**

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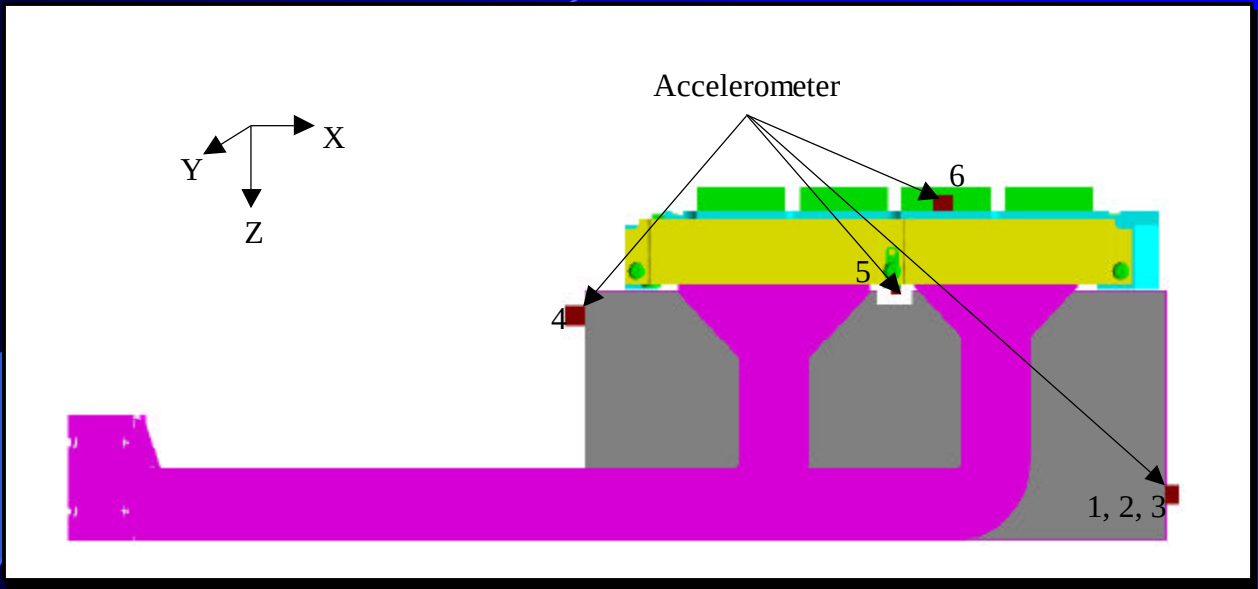
Random Vibration Test Setup



Accelerometer	Direction	Description
1	X	Control for X
2	Y	Control for Y
3	Z	Control for Z
4	Z	Control for Z
5	Z	Focal Plane Cover
6	Z	Focal Plane Housing

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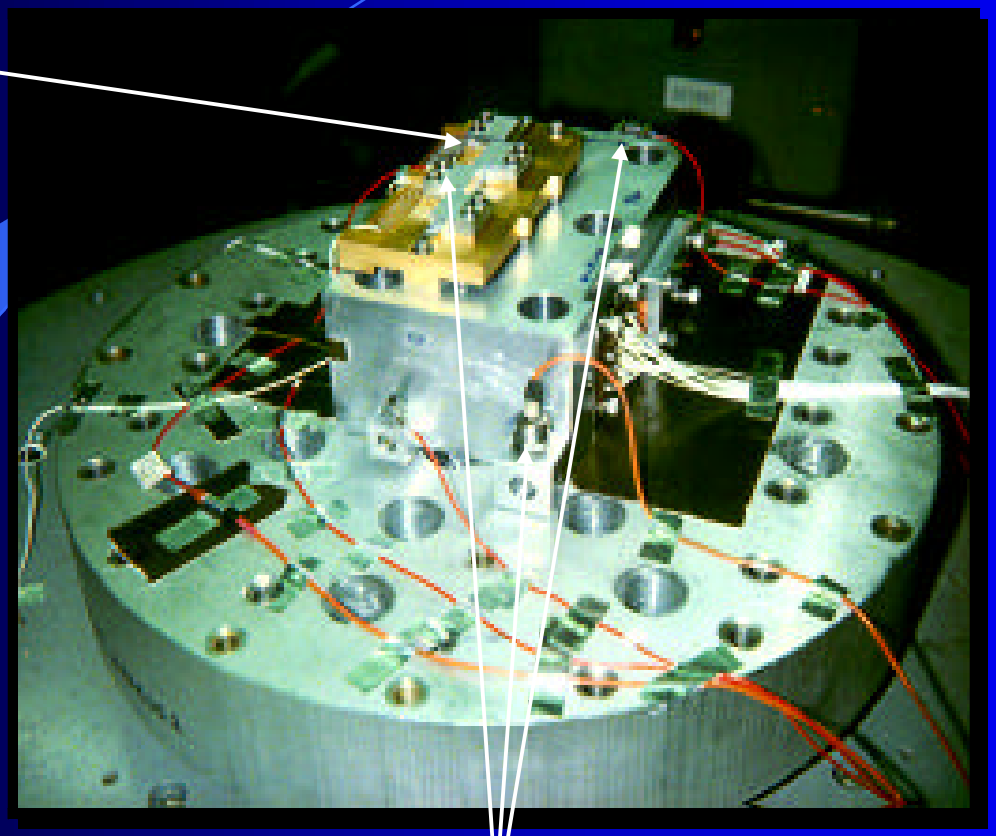
Test Setup

Focal Plane



Accelerometers

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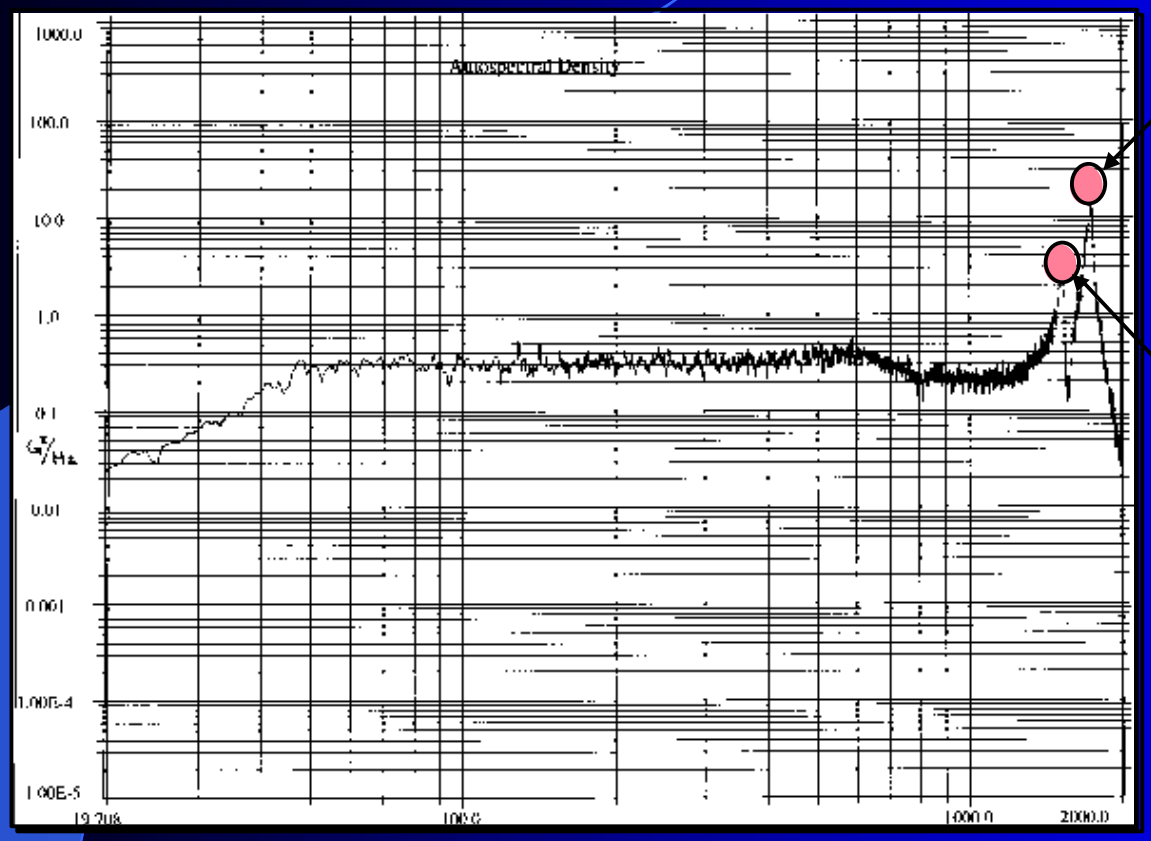
Test Results: Housing



Mode 2: 1717 Hz

Mode 1: 1513 Hz

39.3 G_{rms}

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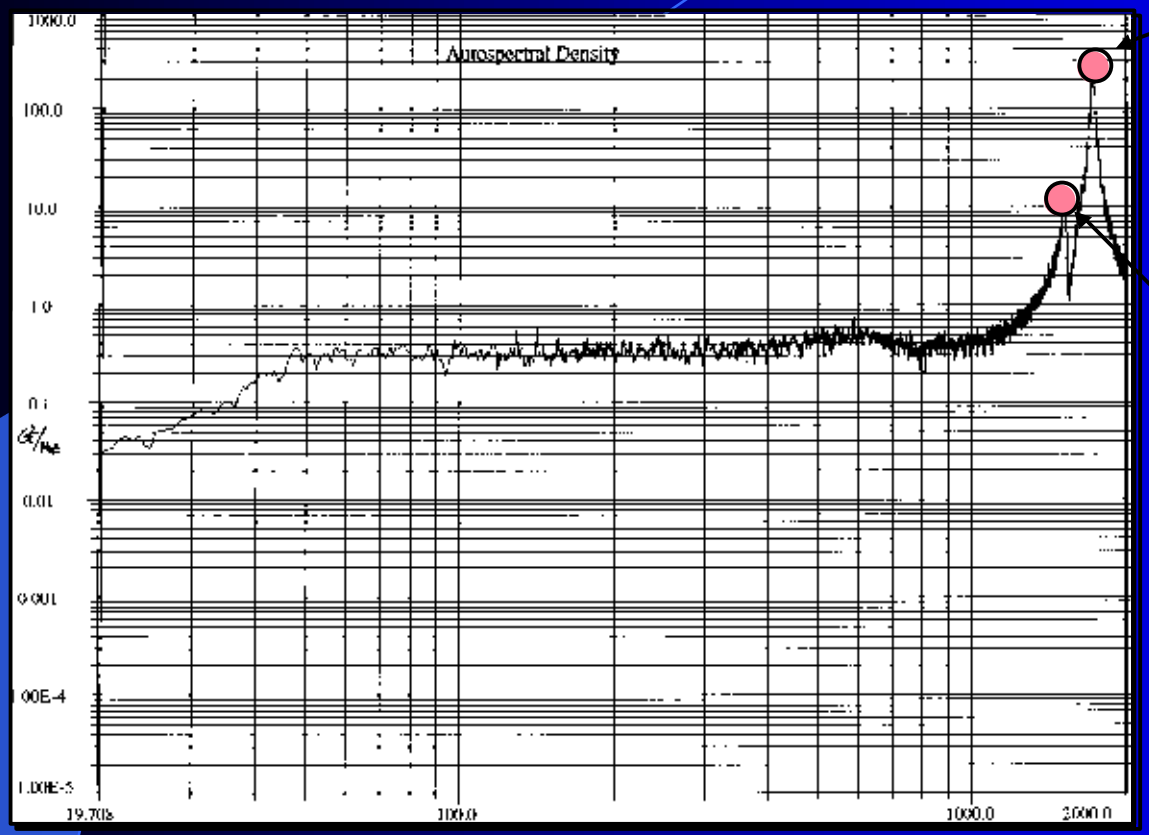
Testing Results: Cover



Mode 2: 1717 Hz

Mode 1: 1513 Hz

118.9 G_{rms}

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What Can Be Derived From Test?

Damping Factors

Mode	Frequency [Hz]	PSD_{in} [G^2/Hz]	PSD_{out} [G^2/Hz]	Amplification Factor	Damping Factor
1	1513	0.019	10.55	23.6	0.02122
2	1717	0.016	193.2	109.9	0.00455

3s Absolute Displacement

Channel	Displacement [mil]	Description
5	1.536	Cover
6	0.912	Housing
Sum	2.448	

Relative Displacement (500 Hz - 2000 Hz): 2.379 +/- mil Using Method Discussed in Appendix B (3% Diff.)

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Method of Correlation

- Match the Frequency of the Test Model
  - Boundary Conditions
  - Mass of Components
  - Stiffness
    - Geometry
    - Material Properties
- Match the Displacement
  - Acceleration PSD Input
  - Damping Value: $\zeta = 1/(2Q)$

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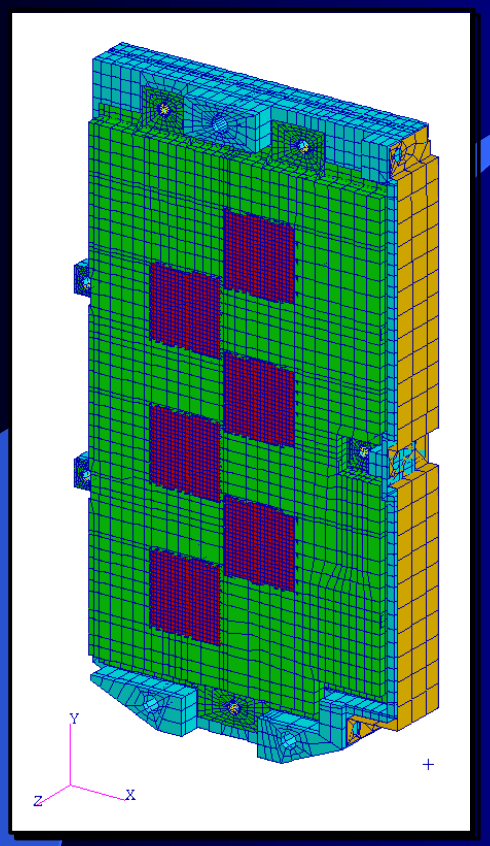
Matching Frequency



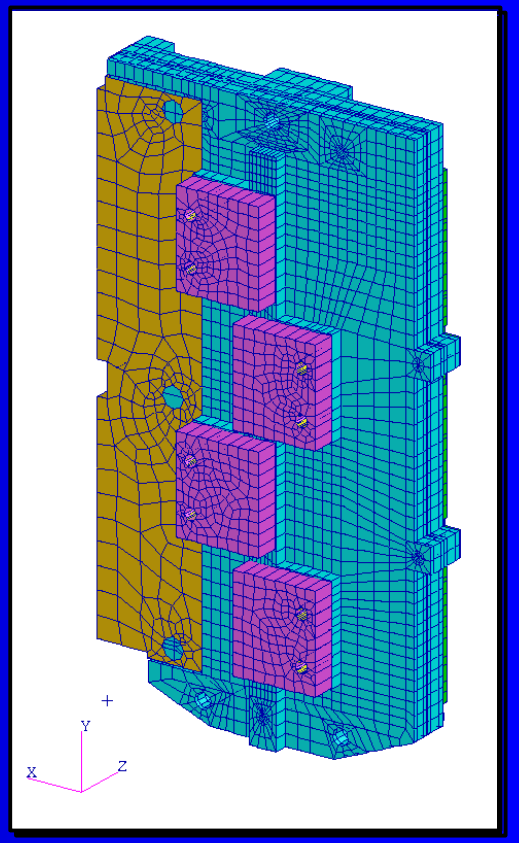
Iso - View

Geometry: Built from Unigraphics Model

Boundary Conditions: Bolt Stiffness Applied

Mass from Tested Components

Materials: Varied Young's Modulus for Molybdenum within range found in multiple sources.



Aniso - View

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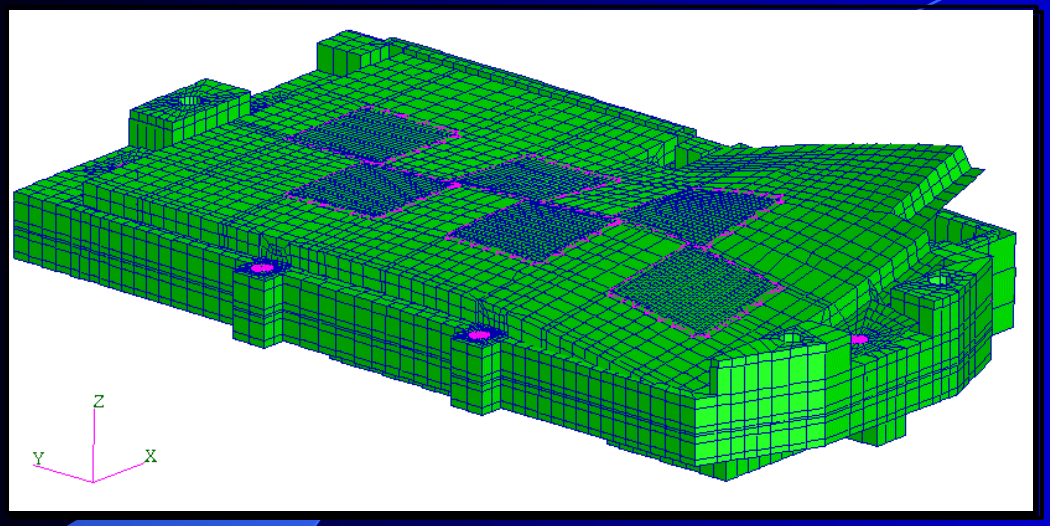
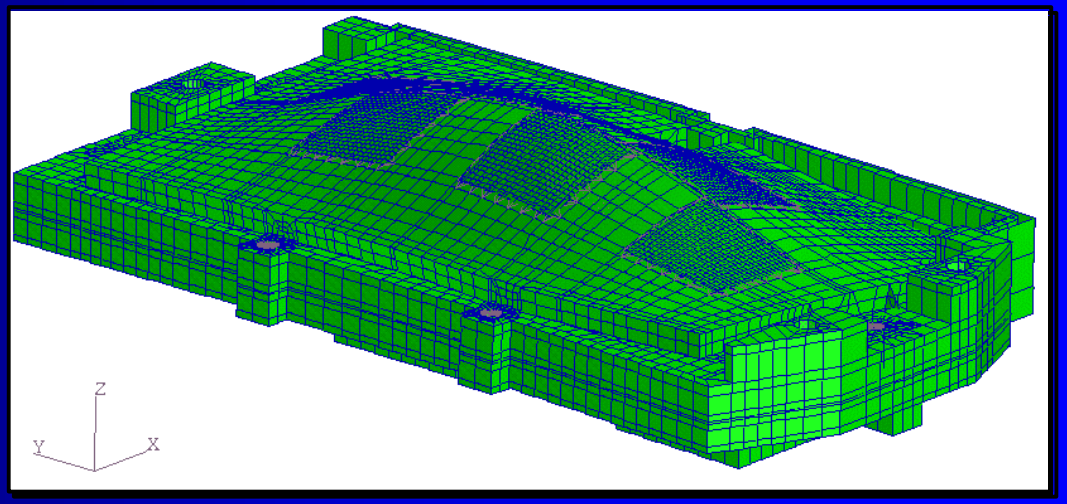
Matching Frequency Results



Mode 1: 1477 Hz
(2.4% Diff)

Mode 1: 1717 Hz
(0.0% Diff)



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Matching Displacement

- Adjust PSD Input to Match Testing.
  - Tolerance allowed for a +1 dB overall variance.
  - For a small response, this makes a large difference.
  - It was found that the PSD input was +0.4 dB higher than Specification.
- Adjust Damping to fine tune the model (z = 0.00351)
- 2.380 mil Deflection (0.042 % diff. from testing) for 500 - 2000 Hz.

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Conclusions

- Bowing due to Thermal Expansion is determined by defining material properties via testing, modeling, and correlation.
- Cryogenic deflections help drive the random vibration allowable.
- Random vibration correlation helps in examining future changes to the focal plane design and it's inputs.

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